

Permanent Freight Data Collection Infrastructure and Archive System

TECHNICAL MEMORANDUM #1

Portland State University

Oregon State University

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1 INTRODUCTION

Truck classification data can be the useful inputs for traffic monitoring programs, freight mobility studies, infrastructure design projects and long-range planning models. Trucking movements have very unique characteristics due to their heavy weight and large turning radii. These characteristics make truck classification an important element for traffic operation, safety and planning. Collecting truck classification data can be a useful tool to relate truck counts, freight mobility studies, and structure design projects. There are several different ways to detect different types of trucks, such as travel surveys, video image detection, and single/dual loop detectors.

The main focus of this part of the project was to review length-based classification schemes, technologies, and to gain a better understanding of how inductive loop sensors and detectors work and to acquire the required parts to set up a test inductive loop detector system. This report present the review in two parts: 1) length-based classification and 2) technology overview.

2 LENGTH BASED CLASSIFICATION

The FHWA's *Traffic Monitoring Guide: Section 4 Vehicle Classification Monitoring* (FHWA 2001) summarizes a number of issues related to vehicle classification by both number of axle and length of vehicles. In many counts, classification is done by visually classifying trucks on the basis of a vehicle's body style. For permanent or long-term counts, vehicle classification is done by either an axle-based or length-based method.

There are several common detection methods for classifying vehicles such as the one above:

- *Axle Sensor Based Counters* - Measuring the number of axles associated with each passing vehicle and the spacing between axles, by computing the speed of the vehicle and the time between axle pulses on each sensor.
- *Vehicle Length Based Counters* - Using two inductive loops estimate the total length of vehicles crossing the loops. Vehicle length is computed by dividing the total time a vehicle is over the loop by the speed of that vehicle. Radar units can also measure vehicle length.
- *Machine Vision Based Equipment* - Machine vision systems are based on video image processing. Camera systems allow the detector to be placed above or beside the roadway; this provides a significant advantage for locations where access to the roadway is extremely limited and expensive, such as high volume urban freeways.

The schematic in Figure 1 below illustrates a typical 5-axle semi-truck trailer combination. Note that both the axle numbers and spacing provide details about the type of vehicle.

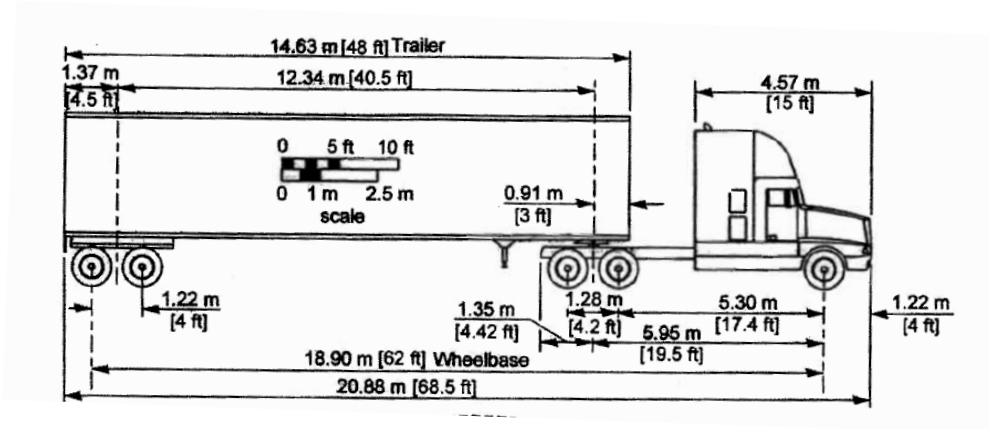


Figure 2-1 Typical 5-axle semi-truck configuration

2.1 State of the Practice

2.1.1 Length-Based Pooled Fund Study

The FHWA recently completed a length-based pooled fund study. The comprehensive study suggested the following:

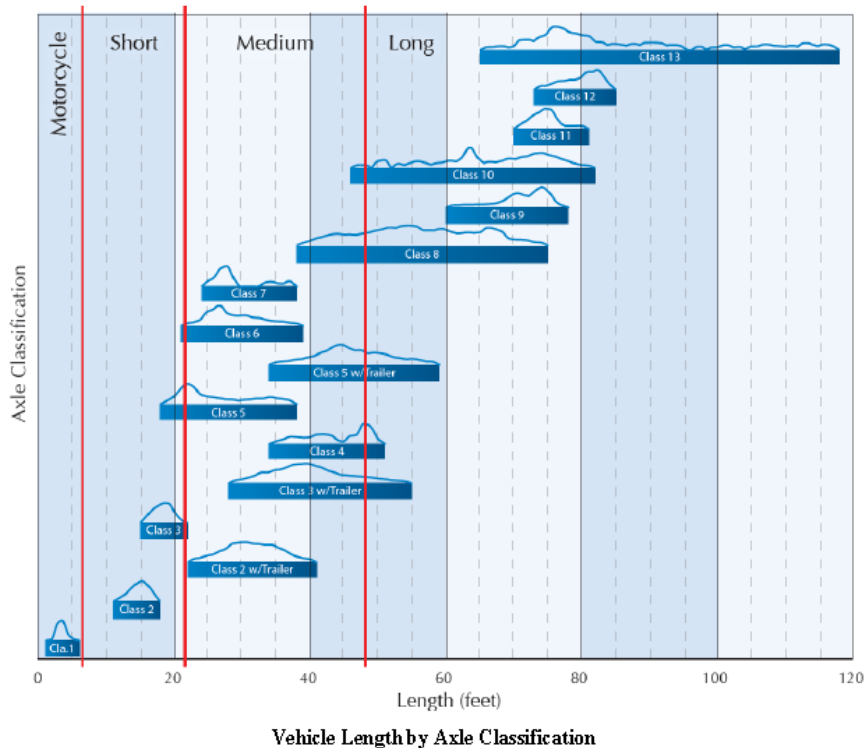


Figure 2-2 From Pooled Fund Study

2.1.2 U.S. Department of Transportation, Federal Highway Administration (FHWA)

The federal classification scheme includes 13 vehicles (see Appendix A). The FHWA classification scheme is separated into different categories. These categories are dependent on whether the vehicle carries passengers or commodities. In addition, the number of axles and number of units create the division between vehicles which carry passengers and vehicles which carry commodities.

In order to correctly classify vehicles into the aforementioned categories, algorithms are needed to interpret axle spacing information. These algorithms must be implemented on automatic vehicle classifiers (ATC). These algorithms are commonly used based on “Scheme F” which was developed by the USDOT in the mid-80s. Table 1 represents “Scheme F”.

Table 1: “Scheme F” Number of Axles per Vehicle

FHWA Vehicle Class	Daily Vehicle Volume	Average Number of Axles Per Vehicle	Total Number of Axles
1	100	2	200
2	1,400	2	2,800
3	45	2	90
4	15	2	30
5	20	2	40
6	40	3	120
7	5	4	20
8	15	4	60
9	120	5	600
10	5	6	30
11	15	5	75
12	5	6	30
13	10	7	70
Total Volume	1,795	Total Number of Axles	4,165
		Average Number of Axles Per Vehicle	2.32

The FHWA does not recommend “Scheme F” or any other classification algorithm. They have concluded that axle spacing characteristics for specific vehicle types vary from state to state thus there is no general spacing standards for all cases. In order to achieve accurate results, it is up to state DOT’s and agencies to develop, test and improve an algorithm.

The FHWA proposed a new classification method, which is based on the aggregation of the “Scheme F” classification. This classification scheme was tested using the combined data from all states.

Table 2 represents the length based classification boundaries and the errors associated with it, respectively.

Table 2: Length Based Classification Boundaries

Primary Description of Vehicles Included in the Class	Lower Length Bound >	Upper Length Bound < or =
Passenger vehicles (PV)	0 m (0 ft)	3.96 m (13 ft)
Single unit trucks (SU)	3.96 m (13 ft)	10.67 m (35 ft)
Combination trucks (CU)	10.67 m (35 ft)	18.59 m (61 ft)
Multi-trailer trucks (MU)	18.59 m (61 ft)	36.58 m (120 ft)

In order to get better results, fine-tuning the length spacing boundaries to account for characteristics of their trucking fleets would improve these errors. However, fine-tuning will not always lead to a perfect length classification scheme since total vehicle length is not a consistent indicator of a vehicle class, thus size and type of misclassification errors should be considered in order to minimize error. The TMG highlights that all of the detection technologies have “difficulty classifying vehicles in conditions where vehicles do not operate at constant speed, where vehicles follow very closely, or where stop and go traffic occurs”.

Using only length, vehicles will almost certainly be classified incorrectly. For example, a 34 feet small tractor-trailer combination would be classified by length as bin 2 (SU). However, knowing it has three axles and the spacing of those axles it would more likely be classified correctly as combination unit (CU) vehicle. Table 3 presents information from the TMG which reports classification errors comparing a length-only classification to a number of axles and spacing classification. Correct classifications are highlighted in bold while incorrect classifications are italicized. The table highlights that length-based classification will have challenges distinguishing long passenger cars and single unit trucks and combination and multi-trailer trucks because of the diversity of configurations.

Table 3: Misclassification Errors Caused By Using Only Total Vehicle Length as the Classification

Classification Based on Total Vehicle Length					
Classification		PV	SU	CU	MU
Based on	SU	17.7%	81.9%	0.4%	0%
Configuration and	CU	0%	1.8%	84.2%	14.0%
Number of Axles	MU	0%	0.1%	20.8%	79.1%

Source: TMG

2.1.3 Washington Department of Transportation (WSDOT)

Washington State DOT uses dual loops in their freeway detection system in order to classify vehicles according to their length. They use four length-based vehicle categories. The four length-based category is described in

Table 4.

Table 4 Four Length-Based Vehicle Categories Used by the WSDOT

Classes	Range of length (meter)	Vehicle types
Bin1	Less than 7.92	Cars, pickups, and short single-unit trucks
Bin2	From 7.93 to 11.89	Cars and trucks pulling trailers, long single-unit trucks
Bin3	From 11.90 to 19.81	Combination trucks
Bin4	Longer than 19.82	Multi-trailer trucks

Wang and Nihan et al. did a study and determined that during peak hours and off-peak hours dual-loop detectors mistakenly assign bin three vehicles to bin four vehicles, however the reverse (bin four to bin three) does not occur. In addition, they found out that dual-loop detectors have problems in differentiating bin two vehicles from bin three vehicles. They also concluded that in off-peak hours, 30 to 41 percent of misclassification errors are observed for trucks.

2.1.4 Wisconsin Department of Transportation (WisDOT)

WisDOT also used dual loop detectors in order to estimate the length of vehicles. They considered a five-length bin classification scheme, however they used a three length bin classification and examined average absolute estimation error. They concluded that errors were too small and when an estimate fell outside of the correct bin a “buffer zone” was created between three bins. Errors were then shown if they were correct or incorrect, in addition to the percent of the error. Table 5 shows the three-bin classification.

Table 5: WisDOT Classification Scheme

Bin	Range
1	0-22ft
2	22-40ft
3	over 40ft

2.1.5 Hawaii Department of Transportation (HDOT)

HDOT classified vehicle length using Autoscope sensor and SmartSensor HD with The Infra-Red Traffic Loggerr (TIRTL). They suggested a 5-class scheme, which is shown in Table 6.

Table 6: HDOT Vehicle Classification

Class	Range	Type
A	0-13 ft	Motor cycle and moped
B	13-22 ft	Passenger vehicle, Truck tractor, Pickup truck, mid-size SUV
C	22-42 ft	Conventional bus and single-unit truck
D	42-62 ft	articulated bus and single trailer combination truck
E	over 62 ft	multiple-trailers combination truck

Using Autoscope sensor and SmartSensor HD, HDOT concluded that the proposed classification scheme tends to minimize the overlapping of vehicle type, however it does not eliminate this deficiency. In addition, they concluded that most of the errors occurred while classifying class C and D.

Using the TIRTL sensor, they concluded that the system provides adequate accuracy of FHWA axle-based classification and it's best if used for industrial freeways. Having said that, TIRTL requires flat pavement without pronounced crowns in order to be deployed and have the best results. In addition, they concluded that the majority of misclassification occurs in the differentiation between class 2 (passenger cars) and class 3 (pickups).

2.1.6 Minnesota Department of Transportation (MnDOT)

In 2005, MnDOT recommended the use of four bins for their length-based classification. Table 7 describes MnDOT's classification.

Table 7: MnDOT Vehicle Classification

Vehicle Type	Vehicle Length	Vehicle Class
Motorcycle	0 to 7 ft	1
Passenger Vehicles (PV)	7 to 22 ft	2 & 3
Single Unit Truck (SU)	22 to 37 ft	4 to 7
Combination Trucks (MU)	over 37 ft	8 to 13

In 2010, Erik Minge conducted research to evaluate non-intrusive technologies for traffic detection. He compared technologies such as Wavetronix Smart Sensor HD, GTT Canoga Microloops, Peek AxleLight and TIRTL. In this research he concluded that a length-based sensor provides better data regarding its accuracy in comparison with the axle-based sensors. In addition, he suggested that different agencies and state DOT's should perform independent analysis of their classification schemes to determine the best result for their existing sensors.

2.1.7 Florida Department of Transportation (FDOT)

FDOT collected data using video capture. The length of vehicles was extracted using specialized analysis software and classified into "Scheme F" of FHWA. They concluded that there were overlaps among vehicle classes 4, 5, 6 and 7 between the ranges of 25 to 40 feet. In addition, they concluded that there are overlaps of lengths of vehicle classes 8, 9 and 10 from 43 to 80 feet. FDOT suggested using a pattern recognition technique in order to get the optimum length threshold to have reasonable correspondence to FHWA "Scheme F". They used the support vector machines (SVM) model and classified vehicles into three bins. Table 8 describes the classification.

Table 8: FDOT Vehicle Classification

Vehicle Class	Vehicle Type	Vehicle Length
1	Passenger Vehicles (PV)	0 to 21.4 ft
2	Single Unit Truck (SU)	21.5 42.4 ft
3	Multi-Unit Truck	Over 42.5 ft

The accuracy of the classification was dependent on whether or not a vehicle towing light trailers was present in the data. The accuracy was 91.1% and 96.0%, respectively.

2.1.8 Ohio Department of Transportation

Ohio State DOT uses three bins for their length-based classification method. Table 9 describes this classification.

Table 9: ODOT Vehicle Classification

Class	Vehicle Length
1	0 to 28
2	28 to 46 ft
3	Over 46 ft

2.1.9 New York Study

New York DOT (NYDOT) uses Miovision VCU (vehicle collection unit) and defines 3 length bins for its length-based classification. Table 10 describes this classification.

Table 10: NYDOT Vehicle Classification

Class	Vehicle Type	Vehicle Length
1	Passenger Vehicles (PV)	0 to 22
2	Single Unit Truck (SU)	22 to 39 ft
3	Multi-Unit Truck	Over 39 ft

2.2 Summary of Length Bins

The TMG recommends that each state explore the resident truck fleet axle spacing and length characteristics to fine tune any length-based classification algorithm. The TMG suggests default length bins that from experience work well for a majority of the states; these are shown in Table 1. We contacted Don Crownover and Tricia Tanner at ODOT traffic monitoring group and they indicated there currently two schemes used: 1) as part and “official” speed monitoring site a 2 bin format of 20 and 150 is used; and 2) at other locations that are not an “official” speed site but is a speed/length sites, 4 bins format of 20, 35, 61, and 150 is used. In Washington, vehicles are divided into slightly different length bins. Table 1 is a summary of vehicle classification length bins from FHWA, ODOT and WSDOT.

Table 11: Length Based Classification Boundaries

Vehicles Classification	Range of Length (in ft)				
	Pooled Fund (Urban)	Pooled Fund (Rural)	FHWA TMG	ODOT	WSDOT
Passenger vehicles (PV)	> 20	> 21.5	> 13	> 20	> 26
Single unit trucks (SU)	20 to 43	21.5 to 49	13 to 35	20 to 35	26 to 39
Combination trucks (CU)			36 to 61	36 to 60	40 to 65
Multi-trailer trucks (MU)	> 43	> 49	62 to 120	61 to 150	> 65

2.3 Peer Reviewed Literature

2.3.1 Length-Based Classification from Single Loops

Because single-loops are a more common deployment for freeway management, a number of papers have explored using single-loop detectors to do the work of dual loops including length-based classification. Wang and Nihan illustrated that for a typical freeway location on I-5 in Washington, the distribution of vehicle lengths clearly indicated a bi-normal distribution with two distinct peaks. Shorter vehicles had a mean length of 5.5 m (18.0 ft) and a standard deviation of 0.9 m (3.0 ft), while long vehicles had a mean length of 22.5 m (73.8 ft) and a standard deviation of 3.6 m (11.8 ft) (Wang and Nihan 2004)(Wang and Nihan 2003).

Coifman presented the new speed estimation techniques from output from single loop detector, compare with dual loop detector measurement. Following the Ohio Department of Transportation length based on classification scheme for dual detectors, the lengths are used to classify vehicles into three bins with divisions at effective vehicle lengths of 28 ft and 46ft.

In 2008, Coifman and Kim from Ohio State University developed a new methodology in order to use single-loop detectors for length-based classification. They also evaluated this methodology to the existing measurements from video and dual-loop detectors. They concluded that classification results from single-loop detectors were very close to those from dual-loop detectors, however they did not suggest the use of single-loop detectors until more research was done.

2.3.2 Length-Based Classification from Dual Loops

A very relevant study was conducted by Zhang et al (2005) in Seattle, Washington. The researchers evaluated the accuracy of dual-loop measurements of volume and vehicle

classifications and developed methods for improving the quality of real-time dual-loop measurements. This was accomplished by comparing the loop detector measurements and ground-truth data collected (video images) at two different locations. Zhang et al found that dual-loop detectors tend to underestimate total vehicle volumes (Bin 3 vehicles often were considered as being in Bin 4) though the reverse never occurs and that dual-loop detectors have difficulties identifying Bin 2 vehicles. Publicly available software (DEDAC) for dual-loop detectors was produced as part of this research effort.

Ai and Wei did a study to evaluate the dual-loop length-based vehicle classification models against the ground-truth vehicle trajectory data extracted from video under different traffic conditions, free flow, synchronized flow and stop-and-go flow. It is important to note that in synchronized flow, traffic flow is lower than that of the free flow. In stop-and-go flow, vehicles will stop within the detection area frequently for at least one time, which was defined by Kerner et al.

In order to develop this new model, ground-truth data was collected from video vehicle trajectory using VEVID (video-capture-based technique) to extract high-resolution vehicle trajectory. They also used a probe vehicle, which was equipped with a Global Positioning System (GPS) traveler data logger to collect traffic pattern data in order to validate parameters that were involved in the new vehicle classification models. They proposed two new models, VC-Sync model (**V**ehicle **C**lassification Model under **S**ynchronized traffic) and VC-Stog model (**V**ehicle **C**lassification Model under **S**top-and-**G**o Traffic).

They concluded that the VC-Sync model significantly increased the accuracy of vehicle classification against synchronized and stop-and-go traffic conditions. Using the VC-Sync model reduced the error to 8.5% as compared to the existing model, which had an error of 35.2%. In addition, using the VC-Stog model reduced the error to 27.7% as compared to the existing model error of 210%.

2.3.3 Length-Based Classification from Video

As part of an earlier effort to do short/long vehicle classification using the existing data stream in Portland, OR, Bertini et al (2006) compared video-based length classification (Autoscope) and an implementation of Wang-Nihan algorithm. In this study they assumed that the dual-loop outputs were from single loops (the algorithm uses volumes, occupancy, speed). Four locations were used:

- I-5 SB at Marine Drive in North Portland, OR
- I-84 WB at Sandy Blvd/37th Ave in Southeast Portland, OR
- I-5 NB at Lower Boones Ferry Road in Tualatin, OR
- OR-217 at SW Hall Blvd. in Tigard, OR

An example of the length-distribution for one lane from the camera analysis is shown below (which appears to be truncated at 50 feet for graphical purposes).

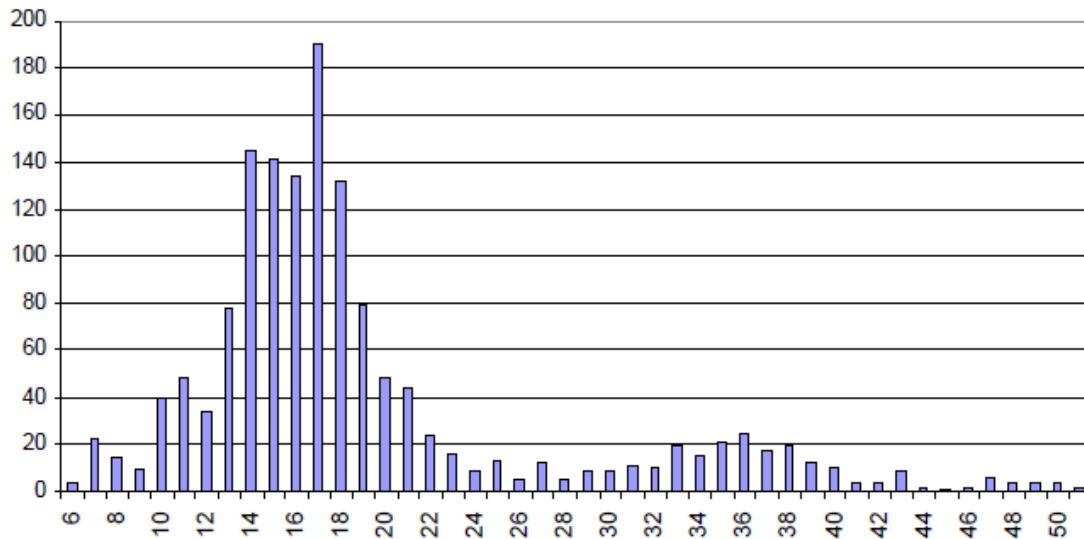


Figure 2: Autoscope Speed Detector Vehicle Length Histogram, Hour 14, Center Lane

Implementation of the Wang-Nihan algorithm using the PORTAL data was less than perfect (as expected). In certain situations, the algorithm did a good job of predicting long vehicle volumes. In others, the algorithm over or underestimates long vehicles. The analysis of the estimation error patterns were inconclusive – there are inconsistencies during period of heavy traffic and light traffic, both when the volume of trucks is low, and when trucks constitute a larger percentage of the traffic stream.

Coifman and Lee also looked at LIDAR (light detection and ranging) technology in order to develop a vehicle classification algorithm. LIDAR technology has been used in different transportation applications in the past, such as highway safety and design. In addition, few research has been done related to vehicle classification. In this study, they separated occluded from non-occluded vehicles. Out of 27,000 vehicles, which were collected from ground truth video, 11% were occluded. From the remaining non-occluded vehicles, 99.5% of them were correctly classified.

3 TECHNOLOGY REVIEW

The primary purpose of this section of the report was to provide the background information required to develop the sensors.

3.1 INDUCTIVE LOOP DETECTORS

As depicted in Figure 1, an inductive loop vehicle detector system consists of three components: a loop (preformed or saw-cut), loop extension cable and a detector.

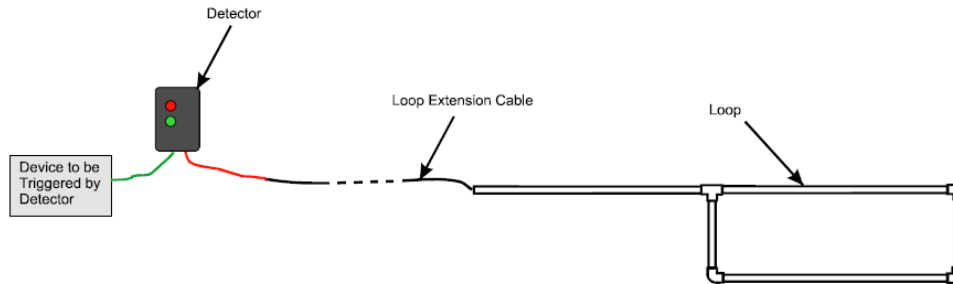


Figure 1. basic components of an inductive loop vehicle detector system

The preformed or saw-cut loop is buried in the traffic lane. The loop is a continuous run of wire that enters and exits from the same point. The two ends of the loop wire are connected to the loop extension cable, which in turn connects to the vehicle detector. The detector powers the loop causing a magnetic field in the loop area. The loop resonates at a constant frequency that the detector monitors. A base frequency is established when there is no vehicle over the loop. When a large metal object, such as a vehicle, moves over the loop, the *resonate* frequency increases. This increase in frequency is sensed and, depending on the design of the detector, forces a normally open relay to close. The relay will remain closed until the vehicle leaves the loop and the frequency returns to the base level.

In general, a compact car will cause a greater increase in frequency than a full size car or truck, as depicted in Figure 2. This occurs because the metal surfaces on the under carriage of the vehicle are closer to the loop.

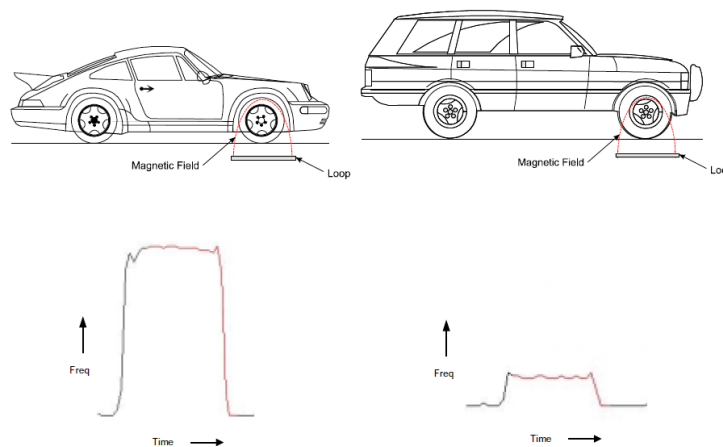


Figure 2. Magnetic signatures of two different vehicle sizes

Detection is based on metal surface area, otherwise known as *skin effect*. The greater the surface area of metal in the same plane as the loop, the greater the increase in frequency. Figure 3 depicts another way to illustrate the point. In the left hand side of Figure 3, a one foot square piece of sheet metal is easily detected by the loop since it is presented in the same plane. However, if this same piece of sheet metal it is turned perpendicular to the loop (right hand side of Figure 3), it becomes impossible to detect.

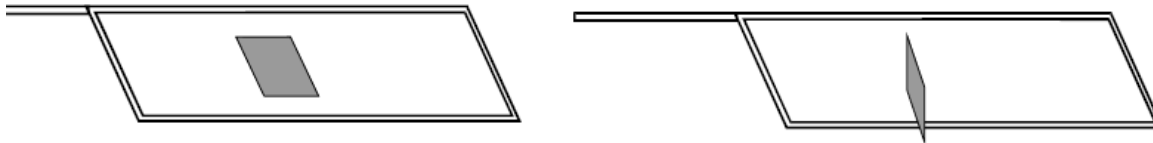


Figure 3. Detection capabilities of an inductive loop detector

3.1.1 Preformed Loops

A preformed loop is typically 3 to 5 turns of loop wire encased in PVC pipe for use in new construction before the pavement is installed. The loop wire is 14 or 16 American Wire Gauge (AWG) stranded machine tool wire with an insulation of cross-linked polyethylene (XLPE) encased in a polyvinyl chloride (PVC) pipe to hold the loop's shape and to protect the loop wire from damage while the pavement is installed.

3.1.2 Saw-Cut Loops

A saw-cut loop is used when the pavement is already in place. The installation involves cutting the loop shape in the pavement with a concrete saw, laying the loop wire in the slot, pressing in a polyfoam backer rod to keep the wire compacted and finishing with saw-cut loop sealant or street bondo to fill the slot and protect the wire.

3.1.3 Loop Extension Cable

A loop extension cable is used to extend the distance from the preformed or saw-cut loop to the vehicle detector, which is usually located indoors or in a weatherproof enclosure. The characteristics of the extension cable are just as important as the characteristics of the loop wire. The use of only 14, 16, or 18 AWG stranded 2 conductor twisted, shielded cable with a polyethylene insulation jacket is recommended. The extension cable connections to the loop wire and the vehicle detector wires must be soldered. The distance between the loop and the detector can safely be extended to 300 feet with proper extension cable.

3.1.4 Number of Outputs

Most detectors provide a switch closure via a relay, which is typically normally configured as open.

3.1.5 Signal Type

All detectors provide a constant presence style of signal output. Some detectors can only provide one or the other style (pulse signal) of signal output at a time.

3.1.6 Diagnostics

Some detectors provide PC diagnostics via a communication port on the detector (see Figure 4). Diagnostic software gives a visual picture of what is happening at the loop, and will help in troubleshooting any problems that may be experienced during installation or in the future. Diagnostics software can also help determine the depth and position of the loop in the pavement.

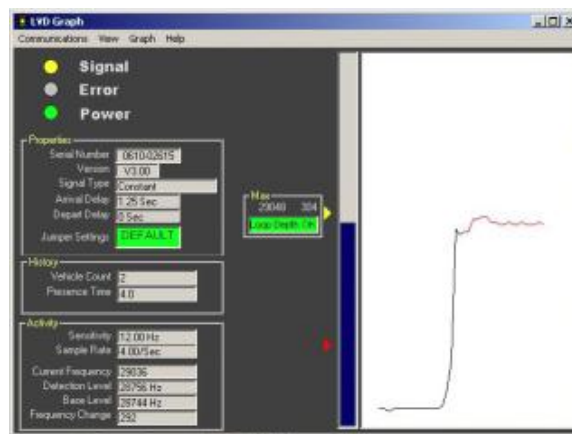


Figure 4. Screen capture of a PC diagnostics program

Diagnostics software is a very powerful tool for diagnostics, is less expensive than the test equipment needed to do the same job and will provide more information. Some diagnostics software will even capture the data to disk. This is especially useful if intermittent problems are common.

3.2 LOOP INSTALLATION AND SENSITIVITY

It is important that when the installation is complete, the loop detector is no more than 2" below the surface of the asphalt or concrete. The deeper the loop, the less sensitive the loop detection system becomes. It is also important that the lead-in wires from the detector to the beginning of the loop be twisted a minimum of five times per foot.

3.2.1 Sensitivity

Most vehicle detectors have adjustable settings for sensitivity. If the detector is missing vehicles, then the sensitivity is set too low. If the detector is jumpy or is creating false detections, it may be too sensitive. The maximum height of detection is roughly 2/3 of the

length of the short side of the loop. Most manufacturers have managed to push the height of detection to the full length of the short side. However, it is important to note that this is not as reliable.

The most effective way to increase sensitivity is to lengthen the short side of the loop. However, making the loop too wide can cause a different problem, i.e., a system that is too sensitive may not be able to identify the gap between vehicles. Increasing or decreasing the number of turns does not affect sensitivity. Increasing the number of turns increases stability. Three to five turns is ideal for maintaining the proper stability and sensitivity combination.

The frequency of the loop will change as the environment changes. As a result, most detectors are designed to constantly adjust to this slow change in frequency over time. The detector's purpose is to detect rapid changes in frequency. However, inductive loops and detectors are sensitive to temperature. When the temperature of the inductive loop increases, the frequency will decrease, and the opposite is true of the detector.

When the temperature of the detector increases, the frequency will increase. If the temperature of either the loop or the detector increases or decreases too fast, false detections will occur. The loop, buried in the pavement is not likely to change temperature rapidly. However, mounting the detector in the wrong place can cause such a problem. For example, mounting the detector directly in line with a window where it can get a cold blast of air whenever the window is open can result in problems.

The 2/3 rule noted above seems to be a very rough estimation. However, it is good to have it in mind as a rule of thumb. Figure 5 below illustrates the variation of loop sensitivity with vehicle undercarriage height for 6 x 2ft, 6 x 4ft, and 6 x 6ft three-turn inductive loops. The sensitivity of the 6 x 2ft loop is small because of its short length.

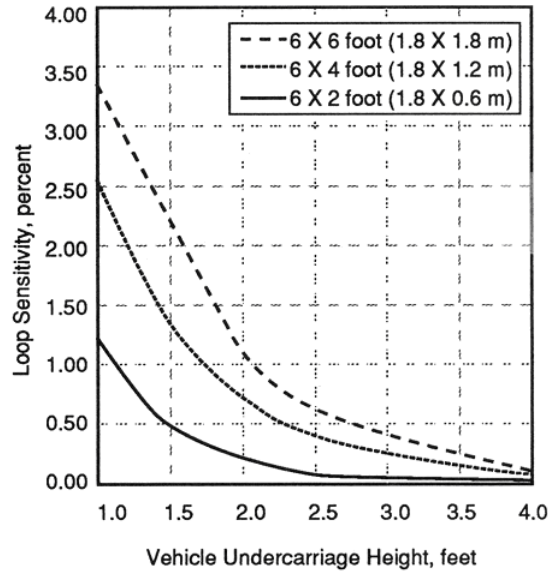


Figure 5. Variation of loop sensitivity with vehicle undercarriage height

In the study “Mapping of Inductive Loop Detector Sensitivity with Field Measurement,” loop sensitivity is defined as:

$$S = \frac{\Delta L}{L} = \frac{L_{NV} - L_V}{L_{NV}}$$

where L refers to a value of inductance, and L_V and L_{NV} refer to the loop inductance with (V) and without (NV) the presence of a vehicle above the loop, respectively. Loop detectors do not measure $\Delta L/L$ directly but rather the more easily measured quantity $\Delta f/f$, i.e., the relative shift in the oscillating frequency of the loop:

$$S = \frac{\Delta L}{L} = \frac{1}{2} \frac{\Delta f}{f} = \frac{1}{2} \frac{(f_V - f_{NV})}{f_{NV}}$$

Six loops were compared in the study with different shapes, as depicted in Figure 6.

- L1, L2: 6ft by 6ft (1.8m by 1.8m) octagonal,
- L3, L4: 6ft round,
- L5: 20ft (6.1m) octagonal, and
- L6: 20ft quadrupole. (two loops in series)

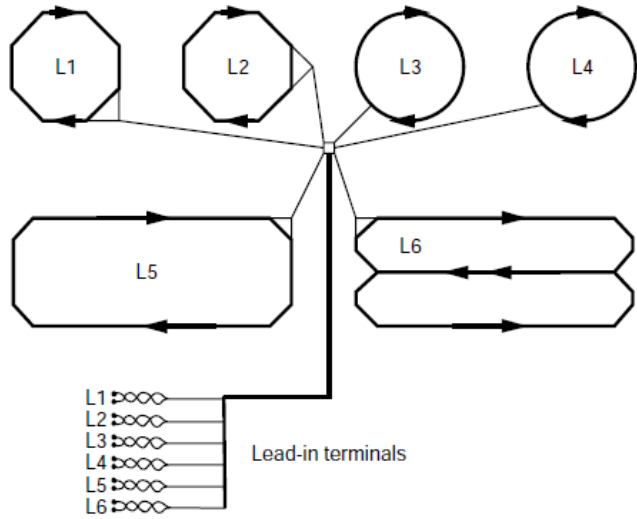


Figure 6. Loop shapes tested

Figure 7 shows a comparison of loop response to galvanized steel installed 12 in. above pavement. The 6-ft loop traces represent the sensitivity of a single loop; multiple loops in series would have overall lower sensitivity.

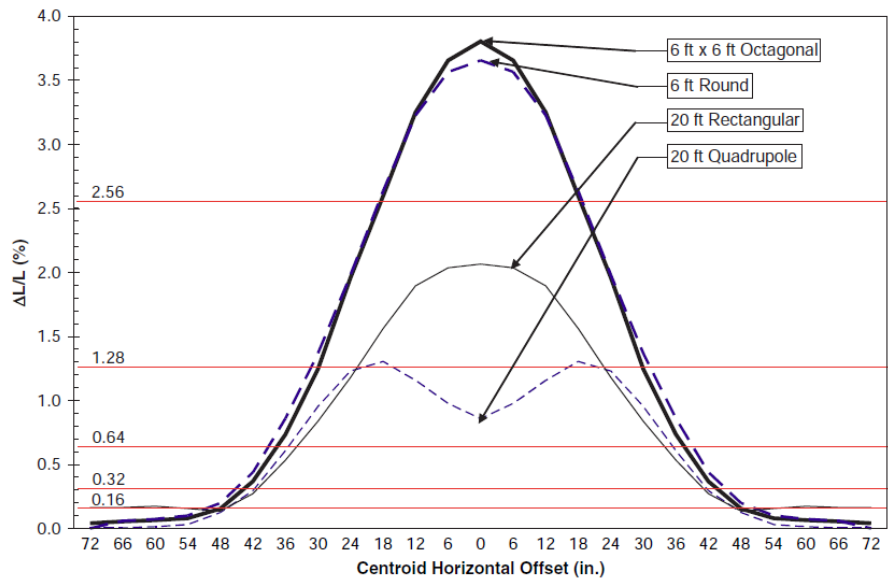


Figure 7. Loop response

3.2.2 Troubleshooting

Most detectors provide LEDs that will indicate a problem with the loop, such as a short or an open. It is possible for a problem to occur that will cause the error indicating LED to stay on and yet the installation is ok, but simply needs a reset. Lightning can cause such a problem. Electrical storms can cause havoc with equipment, especially vehicle detectors because the loop is outside.

3.3 **INDUCTIVE LOOP DETECTOR MANUFACTURERS**

Inductive loop usage is not limited to streets and highways. Today, businesses such as drive thru restaurants, drive thru ATMs, parking lots, and literally anybody who needs to operate something based on vehicle presence can use an inductive loop detector. Therefore, there are lots of manufacturers and brands that produce loop detectors, loops, extension cables and other accessories. Table 1 shows a detailed list of vendors producing NEMA compatible loop detector cards.

Table 1: NEMA compatible loop detector vendors

Company Name	Brand	Product Categories	Inductive loop detector types	Website
Eberle Design Inc.	EDI	Signal Monitors, Inductive Loop Detectors, Load Switches & Flashers, Load Switches & Flashers, Software, Power Supplies	Nema TS-2, Nema TS-1, 170/2070	http://www.editraffic.com
Procon Electronics	Procon	Parking loop detectors, Traffic Loop detectors, PLCs	Single Channel Boxed Loop Detectors (Traffic), Euro Card Loop Detectors (Traffic), Nema Card Loop Detectors (Traffic), Programmable Logic Controller	http://www.proconel.com/
Reno A&E	Reno A&E	Access Products, Traffic Products, Railroad Products	Inductive Loop Detectors Loop Wire &	http://www.renoae.com/

Company Name	Brand	Product Categories	Inductive loop detector types	Website
			Preformed Loops Loop Finders	
Global Traffic Technologies	Canoga™	Traffic Management, Transit Signal Priority, Emergency Vehicle Preemption	Canoga™ C922 and C924 Vehicle Detectors	http://www.gtt.com/

3.3.1 RENO A&E

RENO A&E is located in Reno, Nevada. They started with designing and producing inductive loop detectors and accessories in 1992. Currently, they produce loops, loop detectors, controllers, monitors, power supplies and test equipment. Reno seems to be an expert in loop detectors in the US. They have a wide variety of loop detectors, from very basic cheap models (non-programmable) costing a few hundred dollars to more advanced loop detectors equipped with loop processor. The company has patented several technologies in loop detectors such as “TrueCount” and “Audible detect signal.” The company provides all the required documents (manuals, data sheets, operating instructions, etc.) for their detectors online.

This is the list of RENO A&E traffic shelf mount loop detectors:

- The L series detectors are one channel detectors with full featured LCD interface.
- The S series detectors are two channel detectors with full featured LCD interface.
- The U series detectors are four channel detectors with full featured LCD interface.
- The T-100 series detectors are one channel detectors with DIP switch user interface.
- The T-110 series detectors are one channel detectors with DIP switch user interface.
- The T-210 series detectors are two channel detectors with DIP switch user interface.
- The T-400 series detectors are four channel detectors with DIP switch user interface.

There are also rack mount products available on their website (with a different name coding)

RENO A&E produces both loop wire and lead-in cables. Loop wires are available in single and multiple conductor types for performed and saw-cut loops. In addition to loop detectors and wires, Reno also manufactures the following hardware:

- DC Isolator
- Switch Panels
- Card Racks

- Power Supplies
- BIU (converts detector signal to serial signal)
- Monitors
- Test Equipment
- Harnesses
- Load Switches
- Flashers
- Transfer Relay

3.3.1.1 Comparison of Two Reno A&E Shelf Mount Loop Detectors

In this section, two different Reno shelf mount loop detectors are compared: model L-1201-SS (one channel LCD) and model T-100-SS (non-LCD).

3.3.1.2 Model L-1201-SS

The L series detectors are one channel detectors with full featured LCD interface. Figure 8 depicts the loop detector model L-1201-SS.



Figure 8. Reno's L-1201-SS loop detector

The L-1201-SS loop detector has the following operational characteristics:

- Meets or exceeds NEMA TS 1 specification
- Patented Audible Detect Signal on all versions.
- TrueCount™ version available

The diagram shown in Figure 9 describes the functions and operations regarding each control on the device.

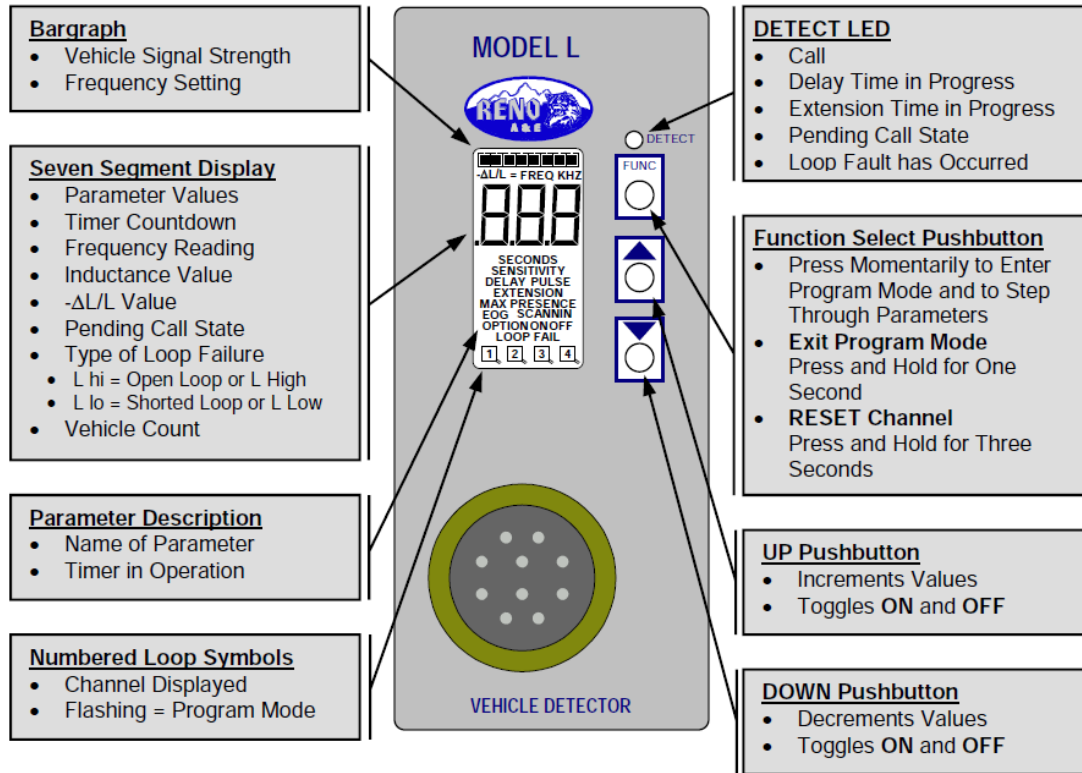


Figure 9. Reno's L-1201-SS loop detector functions

3.3.1.3 Model T-100-SS

The T-100 series detectors are one channel detectors with DIP switch user interface. Figure 10 depicts the loop detector model T-100-SS.



Figure 10. Reno's T-100-SS loop detector

The T-100-SS loop detector has the following operational characteristics:

- NEMA TS1 compatible

- Patented Audible Detect Signal on all versions

The six front panel DIP switches provide:

- Seven levels of sensitivity plus off
- Presence or Pulse mode
- Four loop frequencies
- Dual color, high intensity LED:
 - Green indicates detect
 - Red indicates loop fail
- Space provided on front panel to label detector
- Built-in loop diagnostics
- Relay or Solid-State output versions available

Delay and extension timing settings are programmed with a twelve-position DIP switch module to provide delay timing intervals of 0 to 63 seconds and extension timing intervals of 0 to 15.75 seconds.

The diagram shown in Figure 9 describes the functions and operations regarding each control on the device.

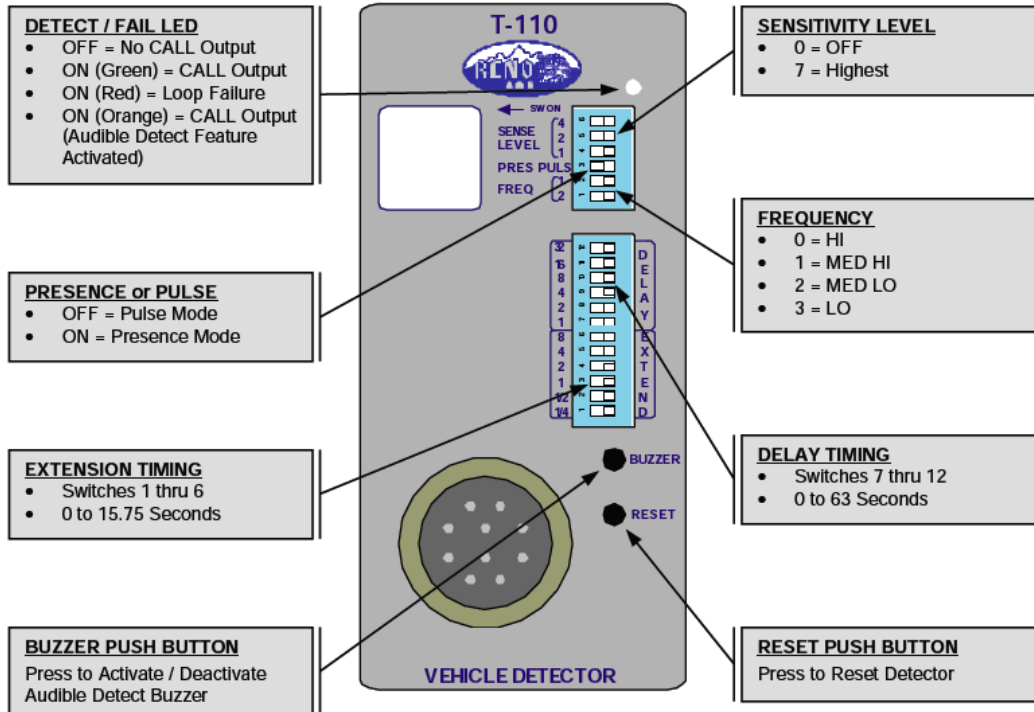


Figure 11. Reno's T-100-SS loop detector functions

3.3.2 Summary

The LCD model (L-1201-SS) has three main features that the DIP switch model (T-100-SS) does not have:

- TrueCount™: provide 97% to 99% count accuracy when used with either a single long loop or multiple 6' x 6' loops connected together.
- Loop analyzer: can measure and display loop frequency, inductance, etc.
- Some extra functions (Phase Green Input, Noise Filter, etc.) which come handy in loop controlled intersections.

When Reno was asked about the possibility of having extra information extracted from loop detectors, their answer was:

- We can bring any information out of the detector.
- The cabinets are wired to accept a high/low detector output.
- NEMA TS2 provides for channel status outputs, which provides loop failure information.
- There is no defined protocol to bring additional information from the Detector.

4 REFERENCES

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5 APPENDIX A

Simple Case Study Using Oregon WIM Data

We did a simple case study to explore the length vehicle distribution of Oregon’s truck fleet. Data were obtained from PSU’s Weigh-in-Motion (WIM) data archive. This archive contains vehicle-level observations that include a timestamp, gross vehicle weight, total length, axle spacing, vehicle type (classified by number of axles and length), and other data. For this particular case study, we chose records from July 1, 2007 to July 31, 2007 at the Woodburn NB WIM station. There were a total of 77,935 records (note that passenger vehicles are not included).

An illustration of the sieve-based classification using number of axles and configuration (spacing) is shown in Figure 2. The vehicles are first classified by number of axles then by spacing into one of the vehicle types (see Appendix). For example, all 3-axle vehicles were classified as either vehicle type 5, 6 or 7 by the spacing patterns. The most common observation (52%) is the 5-axle semi-truck trailer. Note that for this station, no type 3 vehicles (single unit trucks) were classified.

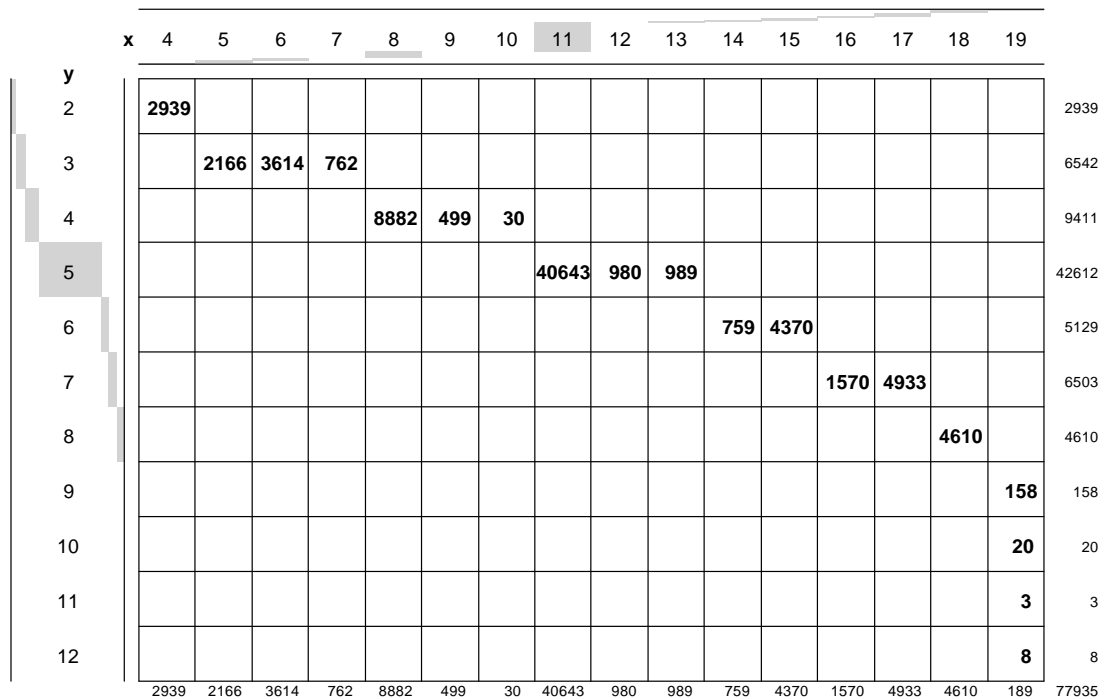
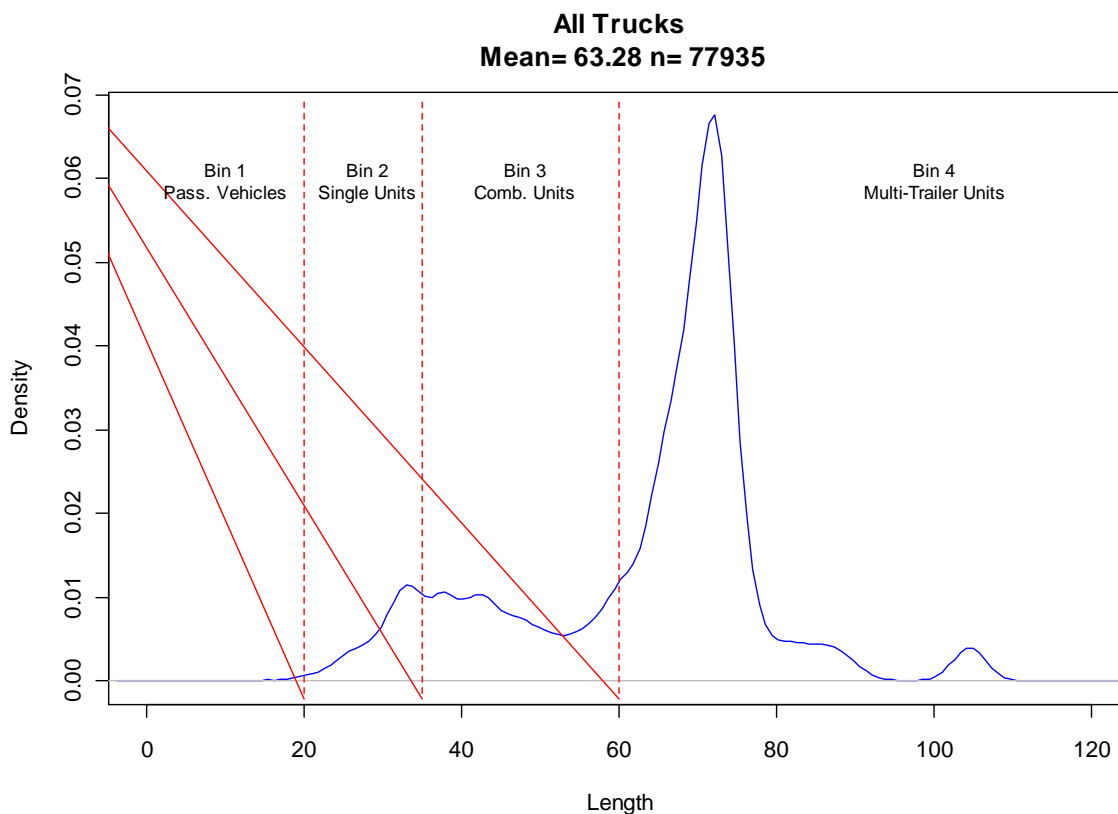


Figure 2: Truck Classification by ODOT WIM, x=Vehicle Type, y=number of axles

Since a length-based algorithm would not have the benefit of knowing the number of axles or the spacing of these axles, it is helpful to explore the length distribution of vehicles that have been classified with both axle and spacing information. As a first step, a kernel density plot of total vehicle length for all trucks is shown in Figure 3 (one can think of kernel density plots as analogous to continuous histograms). The mean length of all trucks is 63.28 ft and clear groupings of truck lengths are shown by the peaks in the kernel density plot. The red vertical lines indicate the boundaries of the ODOT bin lengths (and each bin is labeled). The lower plot is the cumulative plot showing the upper boundary of Bin 4 (60 ft) as the vertical line. From both plots, it can be seen that the majority of vehicles (~70%) are longer than 60 ft and will be classified in Bin 4.



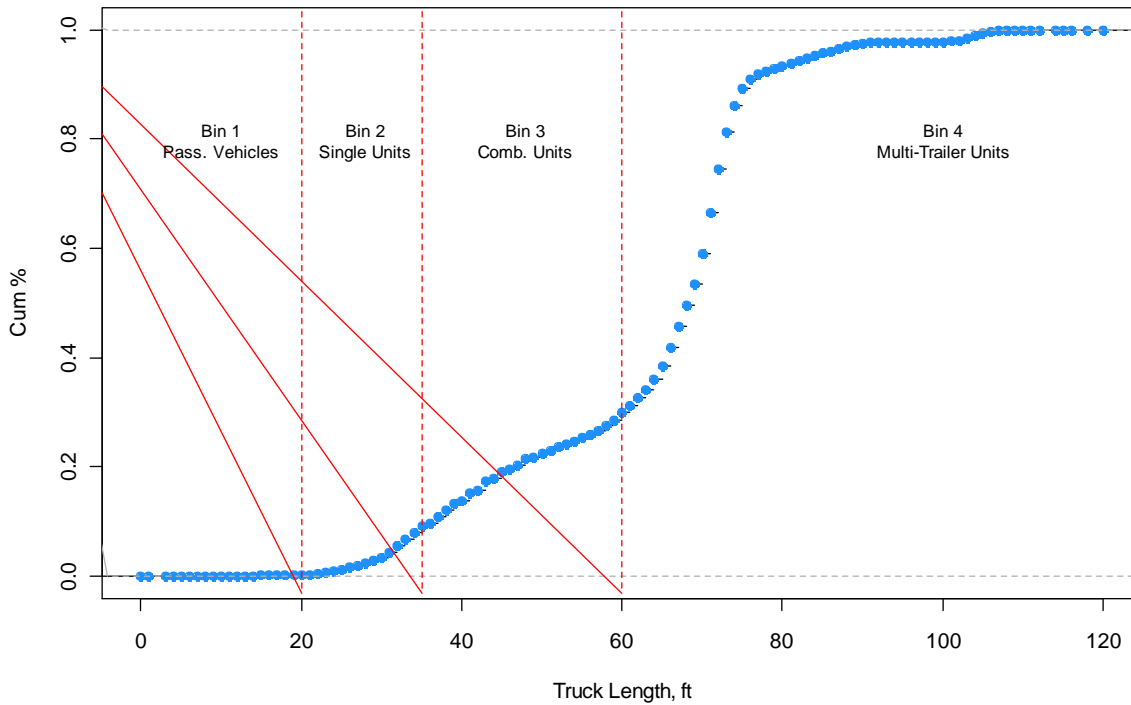


Figure 3: Vehicle Length Density and Cumulative Distribution, July 1-31, 2007, Woodburn NB WIM

As suggested by the TMG, bin boundaries may need to be modified to minimize misclassification for a particular state or region. To demonstrate how this might be done with the robust WIM data, density plots of vehicle length distribution were created for each vehicle type (classified by the WIM station) and are included in the Appendix. Note that data have not yet been cleaned for quality. To illustrate how these plots might be used, the length distribution is shown for 5-axle semi-trucks (the most common truck) with both the ODOT and WSDOT length bins shown as vertical dashed lines in Figure 4. The mean length of these vehicles is 68.4 feet. Both the ODOT and the WSDOT length bins will classify some 5-axle trucks as Bin 3 and the majority in Bin 4. The WSDOT bins do result in a greater share in Bin 3 (a larger area under the density curve in Bin 3). These vehicles should be combination units (Bin 3) and not Bin 4 as multi-trailer vehicles however, with length-based classification some “error” will be unavoidable. Since both Bin 3 and 4 are clearly trucks, the distinction is less important but some fine-tuning of the length bins might be necessary using the WIM data, other classification, or ground-truth data. Using the data, it would be possible to “optimize” the bin boundaries to minimize the desired error threshold.

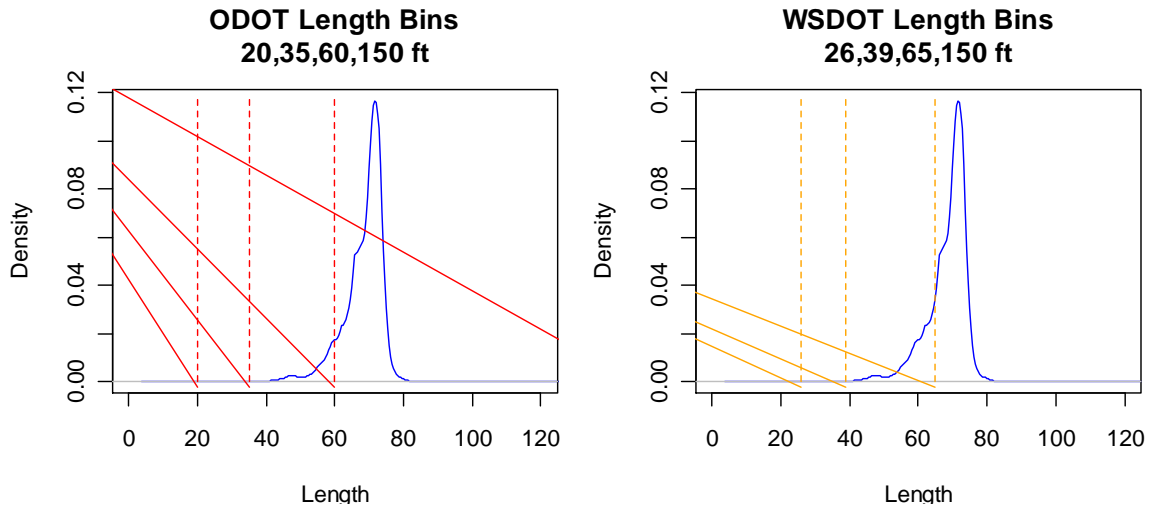


Figure 4: Kernel Density Plot of Vehicle Length, 5-axle semi-truck, Woodburn NB WIM

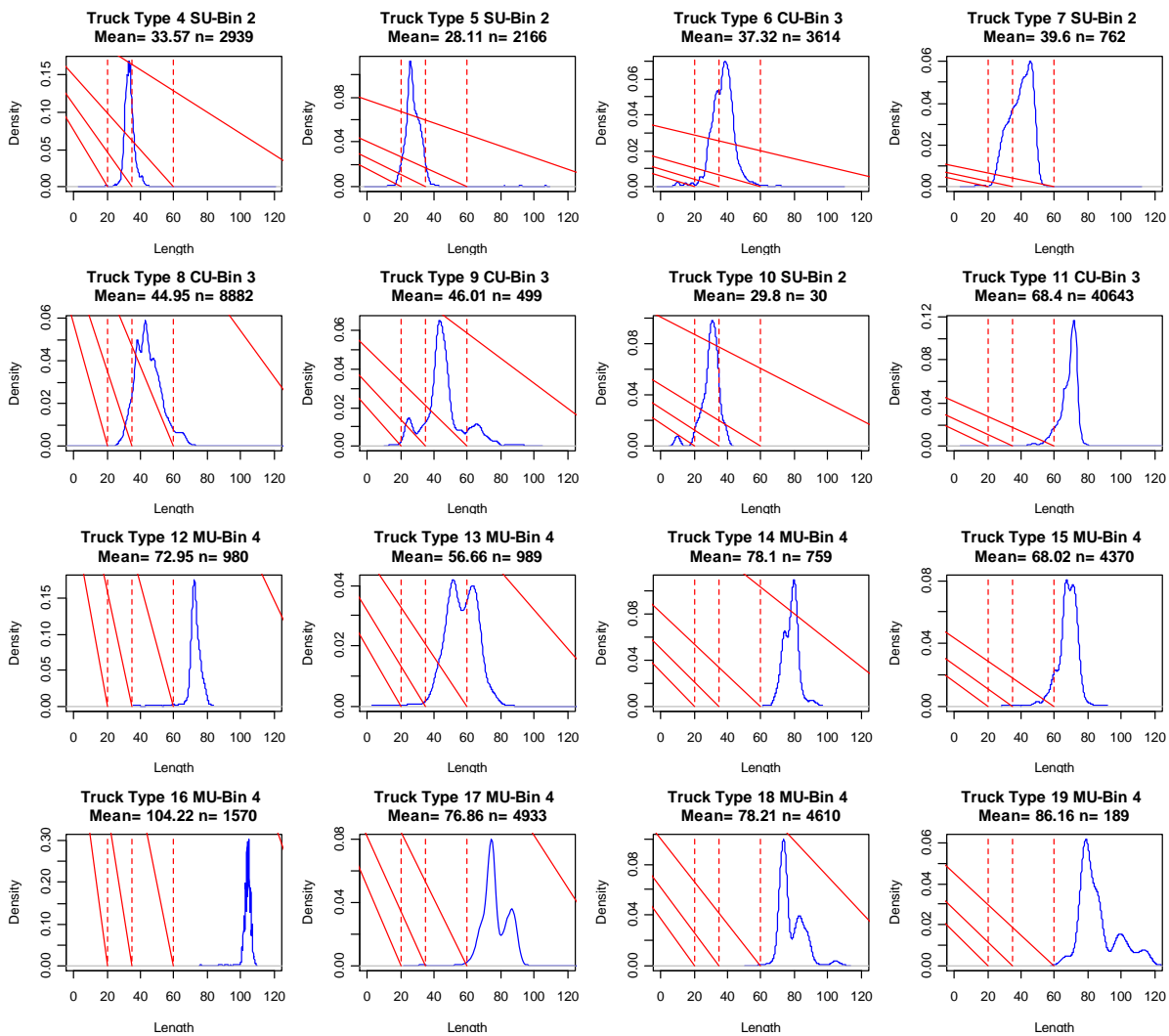


Figure A1: Vehicle Length Density by ODOT WIM Vehicle Type, ODOT Bins

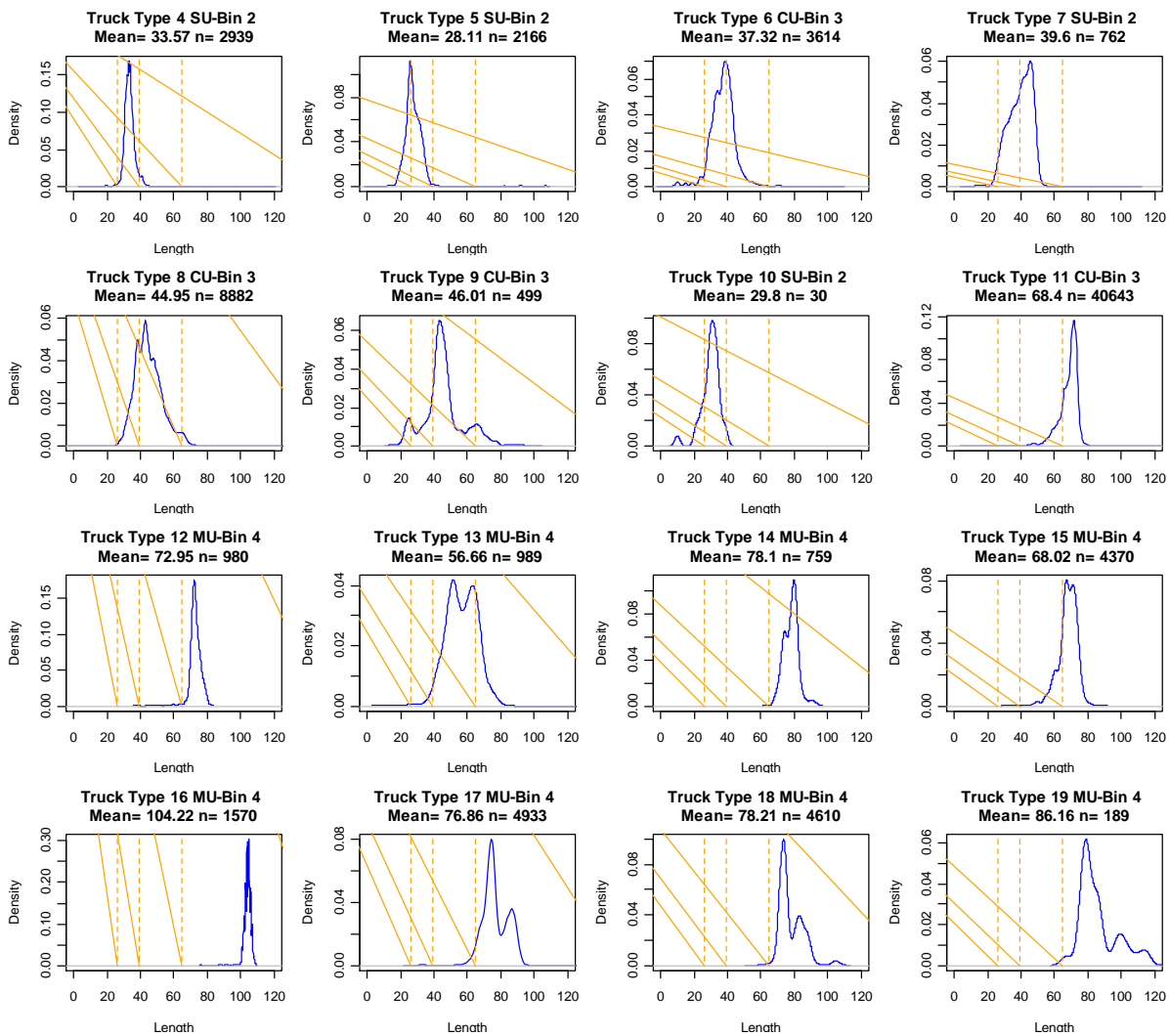































Figure A2: Vehicle Length Density by ODOT WIM Vehicle Type, WSDOT Bins

6 APPENDIX B

- FHWA Vehicle Types -- TMG
- The classification scheme is separated into categories depending on whether the vehicle carries passengers or commodities. Non-passenger vehicles are further subdivided by number of axles and number of units, including both power and trailer units. Note that the addition of a light trailer to a vehicle does not change the classification of the vehicle.
- Automatic vehicle classifiers need an algorithm to interpret axle spacing information to correctly classify vehicles into these categories. The algorithm most commonly used is based on the “Scheme F” developed by Maine DOT in the mid-1980s. **The FHWA does not endorse “Scheme F” or any other classification algorithm.** Axle spacing characteristics for specific vehicle types are known to change from State to State. As a result, no single algorithm is best for all cases. It is up to each agency to develop, test, and refine an algorithm that meets its own needs.
- FHWA Vehicle Classes with Definitions
- 1. **Motorcycles** (Optional) -- All two or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handlebars rather than steering wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheel motorcycles. This vehicle type may be reported at the option of the State.
- 2. **Passenger Cars** -- All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.
- 3. **Other Two-Axle, Four-Tire Single Unit Vehicles** -- All two-axle, four-tire, vehicles, other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, carryalls, and minibuses. Other two-axle, four-tire single-unit vehicles pulling recreational or other light trailers are included in this classification. *Because automatic vehicle classifiers have difficulty distinguishing class 3 from class 2, these two classes may be combined into class 2.*
- 4. **Buses** -- All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. Modified buses should be considered to be a truck and should be appropriately classified.
- **NOTE:** In reporting information on trucks the following criteria should be used:
- a. Truck tractor units traveling without a trailer will be considered single-unit trucks.

- b. A truck tractor unit pulling other such units in a "saddle mount" configuration will be considered one single-unit truck and will be defined only by the axles on the pulling unit.
- c. Vehicles are defined by the number of axles in contact with the road. Therefore, "floating" axles are counted only when in the down position.
- d. The term "trailer" includes both semi- and full trailers.
- 5. ***Two-Axle, Six-Tire, Single-Unit Trucks*** -- All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., with two axles and dual rear wheels.
- 6. ***Three-Axle Single-Unit Trucks*** -- All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., with three axles.
- 7. ***Four or More Axle Single-Unit Trucks*** -- All trucks on a single frame with four or more axles.
- 8. ***Four or Fewer Axle Single-Trailer Trucks*** -- All vehicles with four or fewer axles consisting of two units, one of which is a tractor or straight truck power unit.
- 9. ***Five-Axle Single-Trailer Trucks*** -- All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.
- 10. ***Six or More Axle Single-Trailer Trucks*** -- All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.
- 11. ***Five or fewer Axle Multi-Trailer Trucks*** -- All vehicles with five or fewer axles consisting of three or more units, one of which is a tractor or straight truck power unit.
- 12. ***Six-Axle Multi-Trailer Trucks*** -- All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.
- 13. ***Seven or More Axle Multi-Trailer Trucks*** -- All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.
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7 APPENDIX C ODOT WIM CLASSIFICATION

CLASSIFICATIONS USED IN OREGON'S WEIGH – IN – MOTION STUDY			
Vehicle Type		Vehicle Type	
1. 	Cars	13. 	(2-3) Other 5 Axle Combinations
	Panels		(3-2)
	Pickups	14. 	(3-S1-2) 6 axle Combinations
2. 	Light Vehicles w/ trailers	15. 	(2-2-2)
3. 	2 axle, Single Units		(2-S1-3)
4. 	2 axle Buses	16. 	(2-S1-2-2) Triples
5. 	3 axle Single Units	17. 	(3-S2-2) Other 7 Axle Combinations
6. 	(2-S1) 3 axle Combinations		(2-2-3)
7. 	3 axle Buses		(3-2-2)
8. 	(2-S2) 4 axle Combinations	18. 	(3-S2-3) 8 axle Combinations
	(2-2)		(3-S1-2-2)
9. 	(3-S1) 4 axle Single Units	19. 	(3-S2-4) 9 axle or more Combinations
10. 	(3-S2) 5 axle Semis		(3-S1-2-3)
11. 	(2-S1-2) 5 axle Twins		(2-S2-3-2)
12. 			

These are examples of configurations; there are other possible combinations not illustrated.